Species-to-species energy flow in MERA food web assembly

Jade, April 17

Combining the multiple resource solution and the food web assembly procedure introduced in earlier write-ups (where each trophic level was lumped into a big resource for the next level), here a new assembly procedure is developed where the energy flow between each pair of species from adjacent trophic levels is manifested.

1 The new procedure: species as resources

Entry of a new species into the community is still governed by comparative advantage analysis as in the previous procedure. However, when calculating the steady state abundance for the species at trophic level i, instead of taking all species in trophic level $i-1$ as a big resource ($= R \times (\tau/2)^{i-1}$), treat each species in trophic level $i-1$ as a distinct type of resource, the per capita energy content of which is the resource requirement θ of that species. This is consistent with the first law of thermodynamics: the more energy an individual requires, the more it contains. Then calculate the steady state abundance using the multiple resource solution. Notice that this could give a different result from the lumping assumption when D_r is not a universal val ue for all species. Specifically, the competitor species with higher D_r will benefit from a more even energy content distribution among the resource species.

(To see this, let's recall the multiple resource solution:

$$\frac{\hat{N}_i}{\hat{N}_j} = \frac{\theta_i^{\frac{1}{D_{r,i}-1}} \sum_k^{R_0} C_k^{\frac{1}{D_{r,i}-1}}}{\theta_j^{\frac{1}{D_{r,j}-1}} \sum_k^{R_0} C_k^{\frac{1}{D_{r,j}-1}}} \tag{1}$$

C_k is a constant for all species in the the same sub-community competing for resource type k that is positively correlated to its total energy content. When $D_{r,i} > D_{r,j}$ and all else equal, $\frac{\hat{N}_i}{\hat{N}_j}$ is the highest when C_k is the same for all k.)

For this particular reason, when new entry happens, not only the species in the trophic level where the new species is added are affected, but also the species in higher trophic levels due to a change in energy content distribution in their food resources, i.e. species at lower trophic levels. Therefore steady state abundances have to be recalculated for all of these species. This is a bottom-up effect that emerges in the new procedure.

2 Result

In the following, food web structures with energy flow patterns are compared among different D_r assumptions (i - iii. $D_r = 0.1$, 0.5, or 0.9 for all species, iv. D_r is positively correlated with θ, v. D_r is negatively correlated with θ). Different sequences to sample species from the species pool are also compared (small. fav, random or big. fav).

In each of the graph, the dots represent species, the size of which is the body size (θ) of it while the color indicates its total energy content ($\hat{N} \times \theta$, in the unit of the fundamental resource): the deeper the color, the bigger the energy content. The colors are only comparable within the trophic level. The segment connecting any two species between trophic levels indicates energy transmission between them through predation, the width of which is proportional to the amount of energy transmitted.

First different values for the universal D_r are compared:

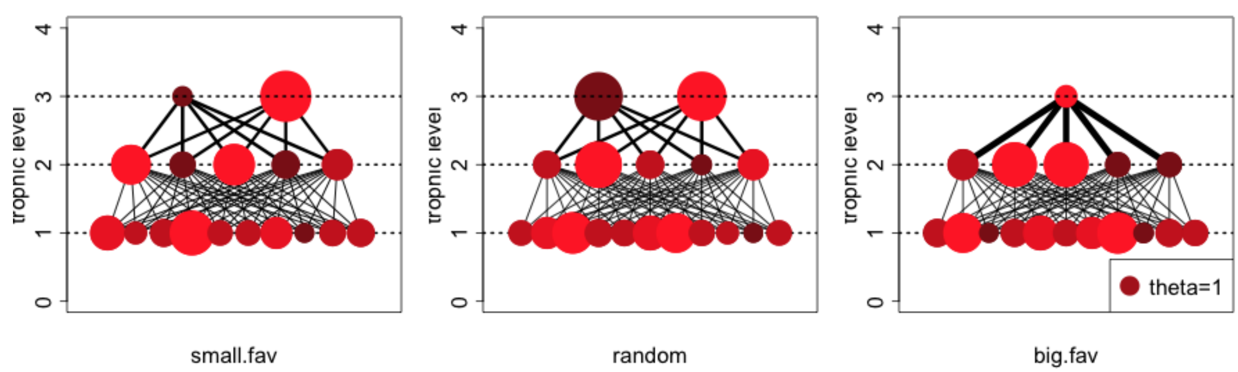

Figure 1. a) Food web and energy flow pattern ($D_r = 0.1$)

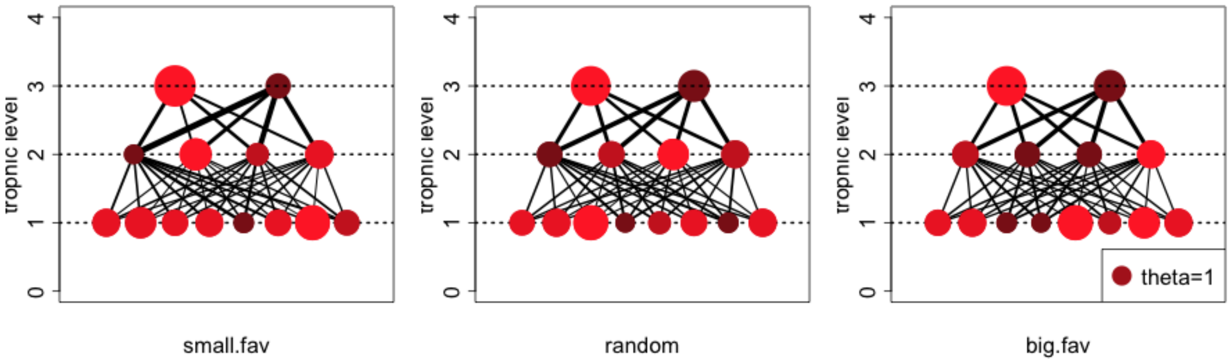

Figure 2. a) Food web and energy flow pattern($D_r = 0.5$)

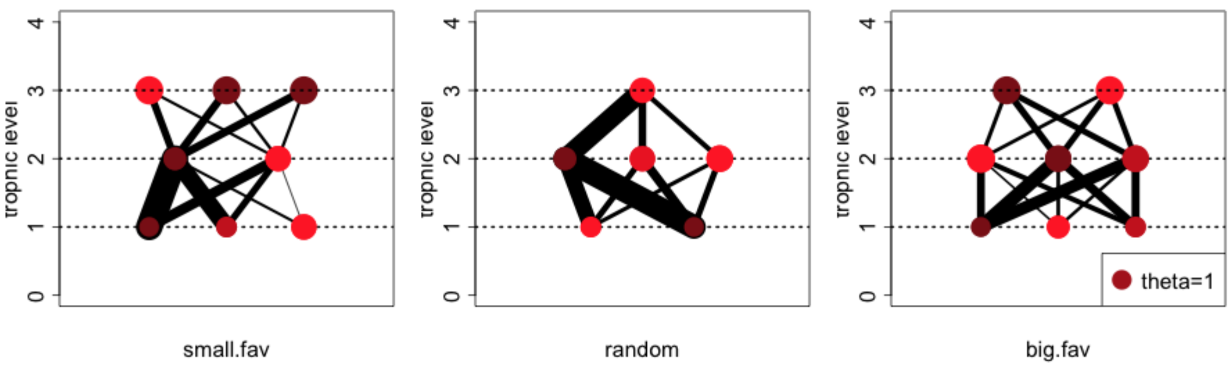

Figure 3. a) Food web and energy flow pattern ($D_r = 0.9$)

From the above we can see that, aside from all the patterns emerging from the previous procedure (e.g. the number of trophic levels relative insensitive to different D_r assumptions and sampling sequences; the number of species and mean body size of the species decrease with D_r)

i. Energy flow between two adjacent trophic level is more unevenly distributed with higher D_r;

ii. The amount of energy flow is positive to the energy content of the two species, i.e. energy flow between two dominant species (dots with darker color) > energy flow between an dominant species and a non-dominant (dots with lighter color) > energy flow between two non-dominant species. Other than a simple reason based on chance, the result from the last write-up has revealed that a dominant species relies more than proportionately on the dominant resource (the one with the highest energy content) while a less dominant species relies more than proportionately on the rare resources. This suggests that the amount of energy flow is more than linearly positive to the energy content of the two species. A different graph might be necessary to better visualize this disproportionality.

In the following, D_r is not the same for all species any more but set proportional to θ or $-\theta$ while being constrained between 0.1 and 0.9.

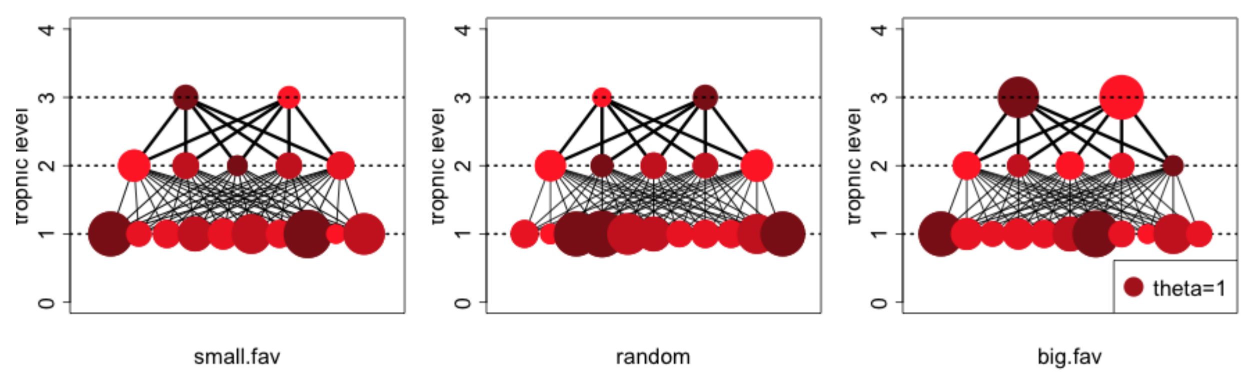

Figure 4. a) Food web and energy flow pattern ($D_r \propto \theta$)

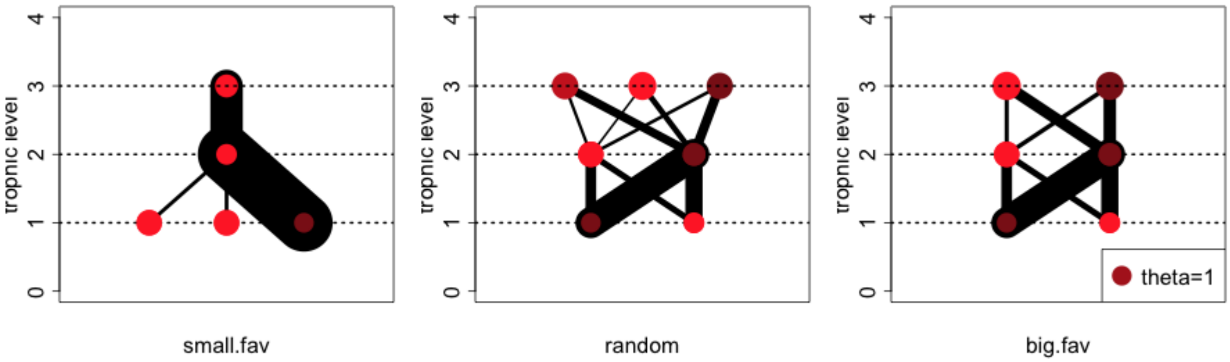

Figure 5. a) Food web and energy flow pattern ($D_r \propto -\theta$)

As addressed in the write-up, these two cases produce very similar patterns with the universal $D_r = 0.1$ and $D_r = 0.9$, respectively, even including the energy flow patterns. This might after all suggest that

iii. Whatever the D_r distribution is like in the species pool, selection into a resource-limited local community might highly favor a very limited range of D_r values, as long as the relationship between D_r and θ is a universal one.

I haven't been able to see any additional interesting patterns from the above graphs. In the appendix I included the graphs showing the community dynamics for each of the assumptions. They look similar to those generated from the lumping procedure (patterns from $D_r \propto \theta$ and $D_r \propto -\theta$ are also similar to patterns from$D_r = 0.1$ and $D_r = 0.9$).

It seems to me that the only way to move on is to find more empirical support for the nature of D_r and its the relationship with θ.

3 Appendix: Community dynamics

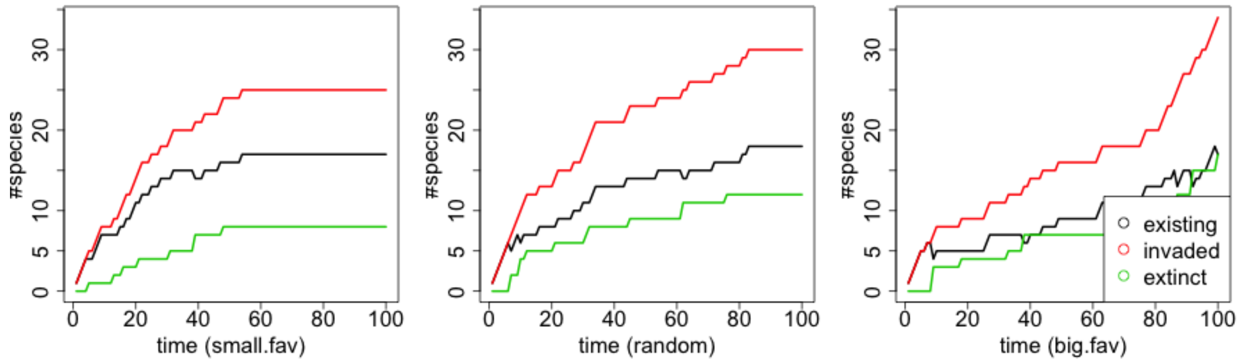

Figure 1. b) Invasion and extinction through time ($D_r = 0.1$)

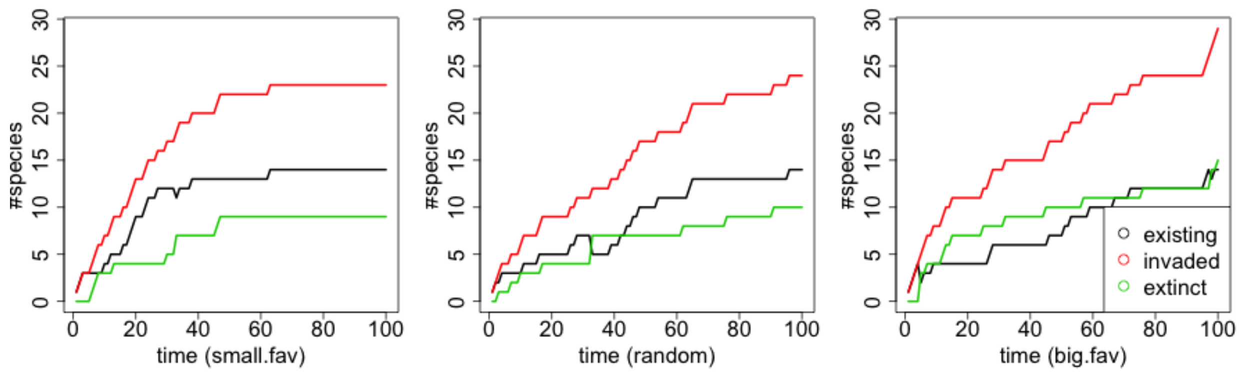

Figure 2. b) Invasion and extinction through time ($D_r = 0.5$)

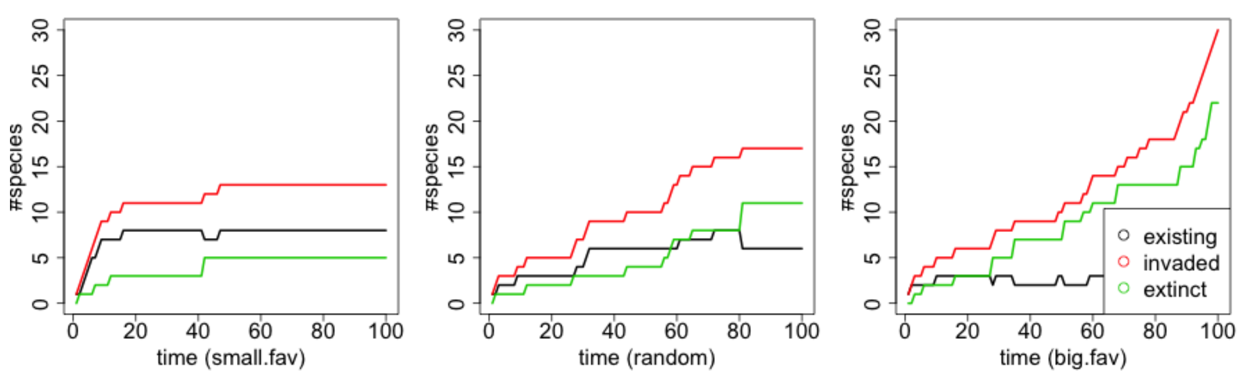

Figure 3. b) Invasion and extinction through time ($D_r = 0.9$)

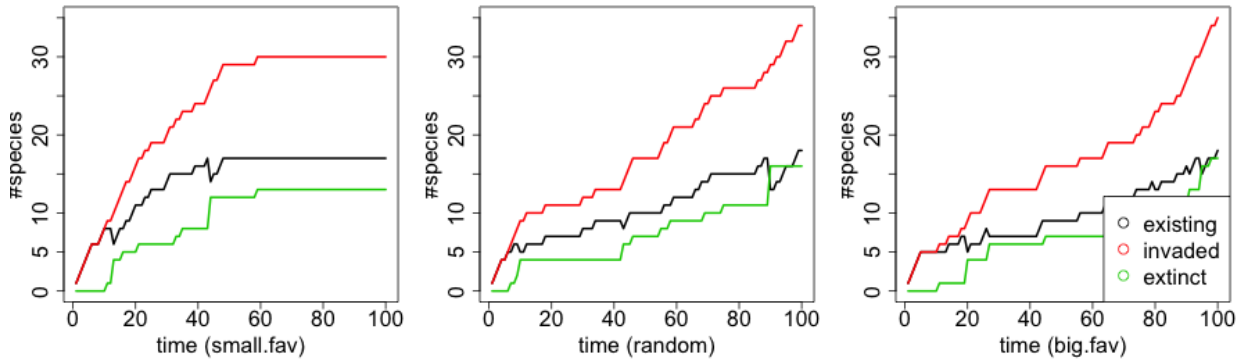

Figure 4. b) Invasion and extinction through time ($D_r \propto \theta$)

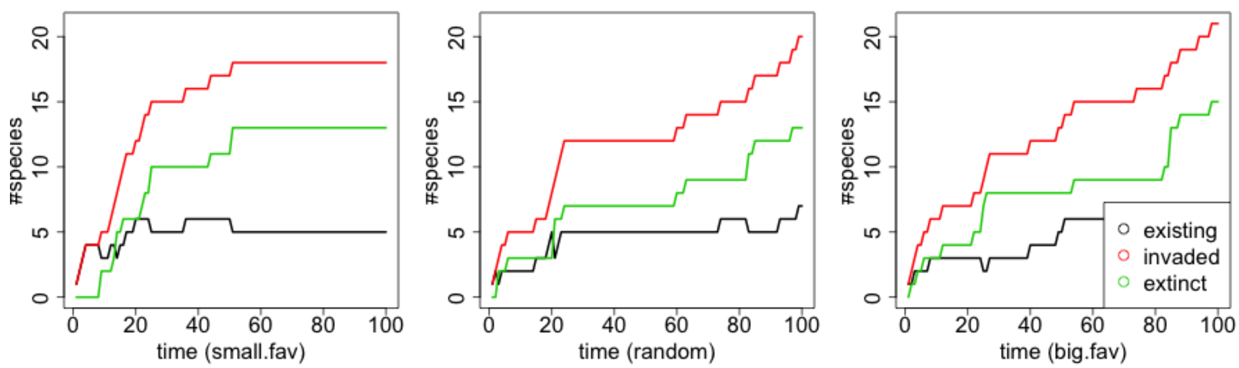

Figure 5. b) Invasion and extinction through time ($D_r \propto -\theta$)